Original Research Article

Omniscient Pte.Ltd.

Research on Fault Diagnosis Techniques for Power Electronic Devices

Hong-Ping Yao[*]

Tangshan Polytechnic College,Tangshan, Hebei 063299,China

*Correspondence to:Hong-Ping Yao,Tangshan Polytechnic College,Tangshan, Hebei 063299,China,E-mail:41424448@qq.com

Abstract: With the rapid development of power electronic technology, the application of power electronic devices in power systems and electrical equipment is becoming increasingly widespread. However, the issue of faults in power electronic devices is also becoming more prominent, posing serious challenges to the stability and reliability of power systems. Based on this, this paper briefly introduces the importance of fault diagnosis for power electronic devices, analyzes the causes of faults in power electronic devices, and discusses fault diagnosis techniques for power electronic devices, aiming to provide theoretical support and practical guidance for the further development of fault diagnosis techniques for power electronic devices.

Keywords: Power Electronic Devices; Fault Diagnosis; Techniques

Introduction

Power electronic devices, as key components in modern power systems, directly affect the stability and operational efficiency of power systems. However, due to the complex and ever-changing working environment of power electronic devices, as well as the complexity of their own structure, the frequency of faults occurring in these devices is high, and the causes of faults are diverse. Therefore, it is of great significance to improve the reliability of power systems and reduce maintenance costs.

1. Importance of Fault Diagnosis for Power Electronic Devices

Power electronic devices serve as core equipment in modern industries, transportation, communications, and other fields. Their stable operation is crucial for ensuring the safety and reliability of the entire system. However, due to the complexity of the structure of power electronic devices, the diversity of working environments, and the increasing operating time, the probability of faults occurring also increases. Therefore, the importance of fault diagnosis for power electronic devices is self-evident.Firstly, fault diagnosis for power electronic devices is crucial for ensuring system safety. Once a power electronic device fails, it may lead to the paralysis of the entire system or even trigger safety accidents. In the transportation sector, for instance, power electronic devices serve as critical components in electric locomotives, high-speed trains, and other vehicles. Their failure may cause loss of control or stoppage of the vehicle, posing a serious threat to passengers' safety.Secondly, fault diagnosis for power

electronic devices is essential for improving equipment reliability. As high-precision and high-reliability equipment, the stability and reliability of power electronic devices directly affect the performance of the entire system. Through fault diagnosis techniques, comprehensive detection and analysis of power electronic devices can be conducted to identify potential hidden faults, thereby taking preventive or corrective measures. Lastly, fault diagnosis for power electronic devices is also significant for optimizing equipment operation and maintenance management.

2. Causes of Faults in Power Electronic Devices

2.1 Complexity of Operating Environments

Power electronic devices, being integral components of modern power systems and electrical equipment, are crucial for ensuring the safety and reliability of the entire system. However, faults in power electronic devices occur frequently due to various factors, affecting not only the normal operation of power systems but also potentially causing significant economic losses and safety accidents. Among the many causes of faults, the complexity of operating environments is a significant factor that cannot be overlooked.(1).Operation in Harsh Conditions: Power electronic devices often need to operate in high-temperature environments. Under high-temperature conditions, components of power electronic devices are prone to performance degradation or damage due to overheating. Overheating may increase the resistance inside components, leading to reduced efficiency of power electronic devices, or even causing serious consequences such as short circuits or component burnouts.(2).High Humidity: High humidity environments are also a significant cause of faults in power electronic devices. In high-humidity environments, the components of power electronic devices are susceptible to moisture, leading to issues such as decreased insulation performance and accelerated corrosion.(3).Vibration and Impact: Apart from high temperatures and humidity, vibration and impact are common factors in the operating environment of power electronic devices. During transportation, installation, or operation, power electronic devices may be subjected to various vibrations and impacts. These vibrations and impacts

may result in issues such as loose connections, cracked solder joints, or component damage. Prolonged vibration and impact may also cause fatigue damage to the mechanical structure of power electronic devices, thereby triggering faults.(4).Electromagnetic Interference (EMI): Power electronic devices may also be affected by electromagnetic interference. In complex electromagnetic environments, power electronic devices may be subjected to electromagnetic radiation interference from other equipment, resulting in errors in signal transmission or control malfunctions. Electromagnetic interference may also affect the stability and reliability of power electronic devices, increasing the probability of faults.

2.2 Design and Manufacturing Quality Issues

Due to various factors, power electronic devices may encounter a series of issues during the design and manufacturing process, which often become significant causes of device failures.(1).Design Defects: Design flaws are common causes of faults in power electronic devices. If the working environment, operating conditions, and usage requirements of devices are not adequately considered during the design process, it may lead to design flaws, resulting in failures. For instance, improper circuit layout may increase electromagnetic interference, affecting the normal operation of devices. Improper heat dissipation design may cause devices to overheat during operation, potentially leading to component burnouts.(2).Improper Material Selection: Improper material selection is another critical factor leading to faults in power electronic devices. The components and materials of power electronic devices have a significant impact on their performance and service life. If the selected materials do not meet the environmental and performance requirements of the devices, it may lead to failures during operation. For example, using materials that are not heat-resistant may cause performance degradation or damage to devices in high-temperature environments.(3).Manufacturing Process Issues: Manufacturing process issues directly affect the quality and performance of devices. Defects in the manufacturing process, such as poor welding or loose assembly, may result in issues such as poor contacts or short circuits during device operation. Moreover, unstable manufacturing processes may lead to performance variations among products in the same batch, increasing the probability of failures.(4).Lax

Quality Control: Lax quality control is also a significant cause of faults in power electronic devices. If there is a lack of quality inspection and control for raw materials, semi-finished products, and finished products during the manufacturing process, it may lead to defective products entering the market, thereby causing failures. Additionally, a lack of monitoring and management of the production process may result in unstable product quality, further increasing the risk of faults.

2.3 Improper Use and Maintenance

In addition to design and manufacturing quality issues, improper use and maintenance are also significant causes of faults in power electronic devices.(1). Improper Operation: Improper operation is a common cause of faults in power electronic devices. For example, incorrect wiring methods, parameter settings, or switching sequences may lead to device failures. (2).Lack of Maintenance: The absence of necessary maintenance measures is also a significant cause of faults in power electronic devices. During operation, power electronic devices may be affected by various environmental factors such as dust, moisture, and temperature. Without regular cleaning and maintenance, issues such as decreased heat dissipation performance, reduced insulation performance, or loose connections may arise.(3).Inadequate Skills and Experience of Maintenance Personnel: The skills and experience of maintenance personnel also influence the fault rate of power electronic devices. If maintenance personnel lack necessary skills and experience, they may not be able to accurately identify and handle device faults. They may fail to detect potential fault hazards in a timely manner or adopt inappropriate repair measures, exacerbating the problem.

3. Fault Diagnosis Techniques for Power Electronic Devices

3.1 Signal Processing Techniques

Signal processing techniques involve the collection and processing of signals such as voltage and current from power electronic devices to extract characteristic information reflecting the device's operating state. These features provide vital insights for fault diagnosis. Various methods and techniques can be employed in signal processing:(1).Fourier Transform: Fourier transform is a commonly used signal analysis method. It converts the time-domain signals of power electronic devices into the frequency domain, allowing observation of the signal's spectral distribution. This facilitates the identification of abnormal components such as harmonics and noise in the signal, aiding in fault detection.(2).Wavelet Transform:Wavelet transform, known for its multi-resolution analysis capability, enables the observation of signal details at different scales. By using wavelet transform, features such as abrupt changes and singularities in power electronic device signals can be extracted, facilitating fault detection with improved accuracy and localization.(3).Machine Learning and Deep Learning: With the advancement of artificial intelligence (AI), fault diagnosis methods based on machine learning and deep learning have been gradually applied to power electronic devices. These methods learn the mapping relationship between fault features and fault types through training on a large dataset of fault data. By inputting real-time signals from power electronic devices into trained models, faults and their types can be quickly determined. This data-driven fault diagnosis approach offers adaptability, accuracy, and real-time capabilities, providing new insights and methods for fault diagnosis.(4).Challenges: Despite the significant role of signal processing techniques in fault diagnosis for power electronic devices, challenges persist. The complex and dynamic operating environment of power electronic devices may affect the quality and accuracy of signals due to noise interference, electromagnetic interference, etc.

3.2 Artificial Intelligence Techniques

As technology rapidly evolves, artificial intelligence (AI) techniques have penetrated various industries, offering new solutions for fault diagnosis of power electronic devices with significantly improved accuracy and efficiency.(1).Machine Learning: Machine learning, a vital branch of AI, has revolutionized fault diagnosis for power electronic devices. Traditional diagnosis methods often rely on human experience and expertise, whereas machine learning automatically extracts fault features and constructs fault models through training on large datasets of fault data. This automation reduces dependency on manual intervention, significantly enhancing diagnosis accuracy and efficiency. Machine learning also dynamically adjusts and optimizes models based on real-time data, improving real-time performance and reliability.2.Deep Learning:

Deep learning, the latest advancement in machine learning, provides robust support for fault diagnosis of power electronic devices. By constructing deep neural network models, deep learning automatically extracts deep features of device faults, enabling precise identification of complex faults. Compared to traditional machine learning methods, deep learning offers stronger generalization and higher recognition accuracy, capable of addressing more complex and diverse fault scenarios. Additionally, deep learning can be combined with other techniques such as signal processing and image processing to form multimodal fault diagnosis methods, further enhancing accuracy and reliability.

3.3 Expert Systems

Expert systems, intelligent systems based on AI technology, simulate the thinking process of human experts and provide reasoning and judgment on specific domain problems using expert knowledge and experience. In fault diagnosis of power electronic devices, expert systems can quickly identify fault locations, analyze fault causes, and propose corresponding solutions based on fault phenomena and equipment parameters.(1).Utilization of Expert Knowledge: Expert systems leverage the knowledge and experience of domain experts, reducing reliance on manual experience in traditional fault diagnosis methods. By constructing comprehensive knowledge bases, expert systems can achieve rapid identification and handling of faults in power electronic devices, improving diagnosis accuracy and efficiency.(2).Strong Reasoning Ability: Expert systems possess robust reasoning capabilities. They automatically search relevant rules and cases in the knowledge base based on input fault information, derive fault diagnosis results through logical reasoning and pattern matching, and

process complex fault scenarios rapidly, enhancing the intelligence level of fault diagnosis.(3).Adaptability: Expert systems can automatically adjust reasoning strategies based on equipment operation status and fault conditions, adapting to different fault scenarios, and ensuring effective fault diagnosis under varying conditions.

Conclusion

In summary, research on fault diagnosis techniques for power electronic devices is an ongoing process that requires continuous introduction of new theories and technical means to address increasingly complex issues. With the continuous advancement of signal processing technology, artificial intelligence, expert systems, and other fields, the accuracy and efficiency of fault diagnosis techniques for power electronic devices will be further improved. In the future, we can expect the emergence of more intelligent and automated fault diagnosis systems, providing more reliable assurance for the stable operation of power systems.

References

[1] Wu, M., & Wang, X. (2019). Analysis of the Application of Advanced Power Electronic Technology in Smart Grids. *China New Communications*, (17), 79.

[2] Ma, R., Wang, J., Ma, X., et al. (2019). Application of Artificial Intelligence in Fault Diagnosis of Power Electronic Circuits. *Encyclopedia Forum Electronic Magazine*, (1), 661-662.

[3] Xu, Z., & Lu, Q. (2019). Application of Power Electronic Technology in Power Systems. *Journal of Electrical Engineering*, (18), 22-23.

[4] Lin, H. (2019). Application of Power Electronic Technology in Electrical Control. *Communication Power Supply Technology*, 36(5), 279-280, 282.